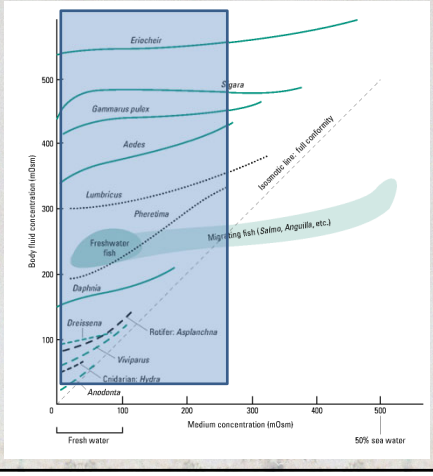
# The moment you leave the sea, water balance becomes an acute issue

Fresh water: an osmotically and ionically hostile environment for animals!



1

# Water budget concept

a balance sheet of gains, storage and losses:

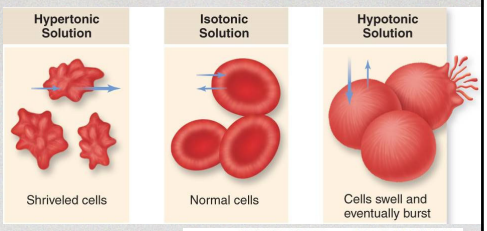
| IN | STORAGE | OUT |
|---|---|---|
| Drinking | Body Fluids | Urine |
| Preformed | Bladder | Faeces |
| Metabolic | | Evaporation (leakage) – body surface |
| Absorption - water | | Evaporation (leakage) - respiratory |
| - soil | | Salt glands |
| - water vapour | | |

2

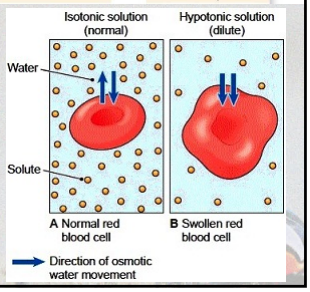
# What happens to cell/animal volume when blood OC changes?

Water freely and quickly permeates across animal cell membranes

Solutes do not. It takes time to redistribute solutes (if you even can).




The opposite is happening in hypertonic solutions




3

# Body Solutes

The intracellular and extracellular fluids contain various solutes that make up the total osmotic concentration.

**The total osmotic concentration of the intracellular and extracellular fluids must be equal [at equilibrium] for animal cells.**

The major solutes are:

- Cations (mainly Na+ and K+)
- Anions (mainly Cl-)
- Urea in some animals
- Other solutes make up the solute gap

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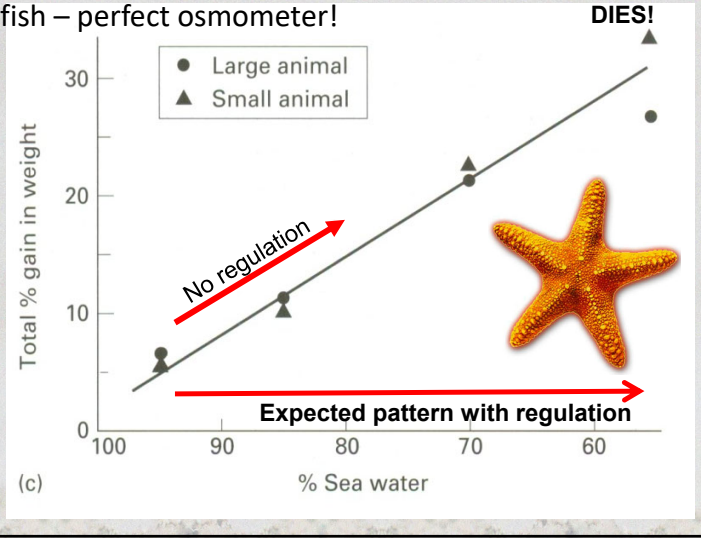
# No osmo and volume regulation

Starfish – perfect osmometer!

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# Low Water and Na+ Permeability in FW, BW compared to SW

The basic starting point for any solution: reduce permeability of skin surfaces

This helps, but doesn't solve the problem: It buys time

**Table 10.4** Values of water permeability ($P_w$) and sodium permeability ($P_{Na}$) in brackish-water animals in comparison with marine and freshwater species and races.

| Genus and habitat | $P_w$ ($10^{-4}$ cm $s^{-1}$) | $P_{Na}$ ($10^{-6}$ cm $s^{-1}$) |
|---|---|---|
| **Bivalves** | | |
| Brackish water | | |
| *Mya* | 3.8 | 5.7 |
| *Geukensia* | 1.3 | 4.0 |
| **Crustaceans** | | |
| Sea water | | |
| *Libinia* | 12.8 | 13.2 |
| *Porcellana* | 4.7 | 1.0 |
| *Eupagurus* | 12.4 | 1.6 |
| *Maia* | 3.4 | 12.9 |
| *Carcinus* | 9.0 | 5.0 |
| 50% sea water | | |
| *Carcinus* | 2.8 | 5.0 |
| *Cancer* | 1.3 | 2.7 |
| Fresh water | | |
| *Eriocheir* | 0.22 | 0.87 |
| *Astacus* | 0.88 | 0.10 |
| **Vertebrates** | | |
| Fresh water | | |
| *Carassius* | 3.9 | 0.4 |
| *Salmo* | 1.6 | 0.3 |
| *Anguilla* | 1.2 | 0.6 |

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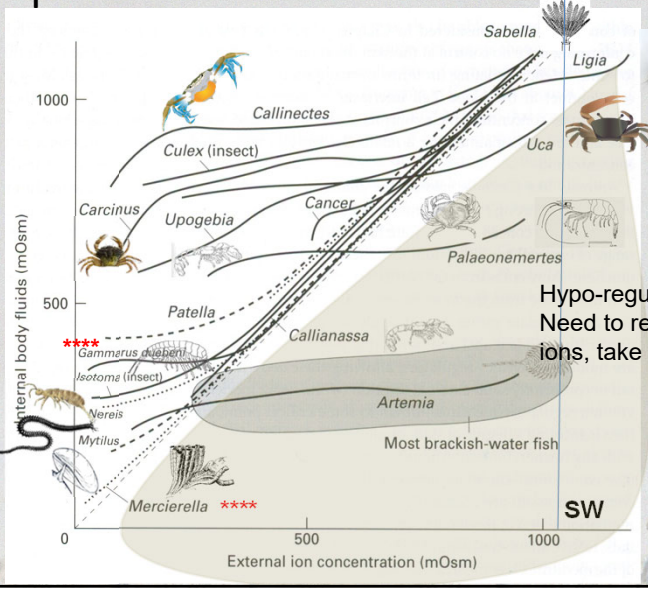
# Hypo-osmotic regulation regulation – same problem in the ocean and on land




Hypo-regulation
Need to remove excess ions, take on water

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# Saline Biota

Typically low diversity

- Blue-green algae, flagellates, halobacteria
- Brine shrimp (*Artemia*, *Parartemia*)
- Crustaceans (fiddler crabs)
- Desert pupfish (hot, up to 140 ppt)
- Brine fly, mosquito and chironomid fly larvae

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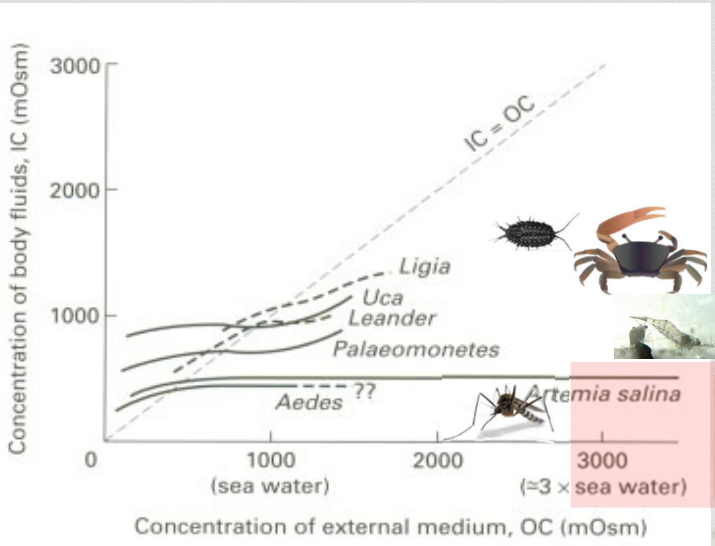
# Artemia is a champion!



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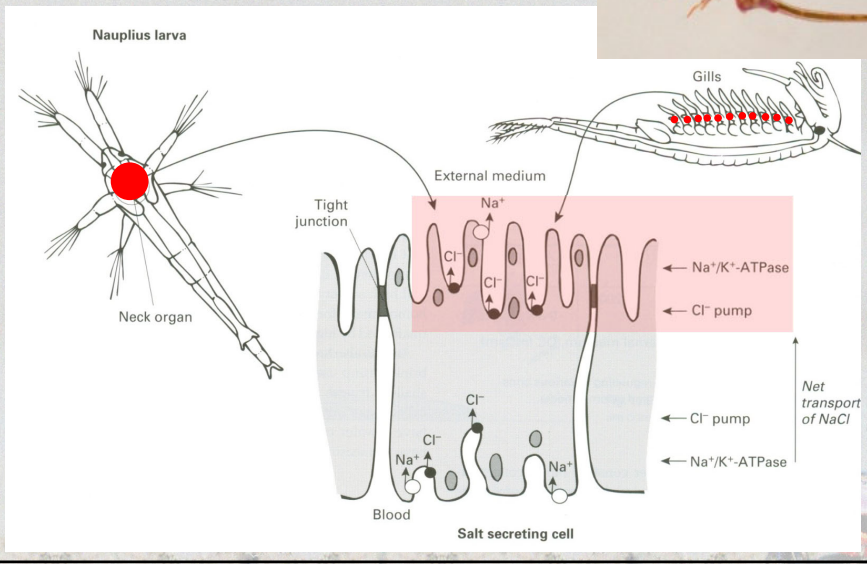
# Cuticular salt pumps

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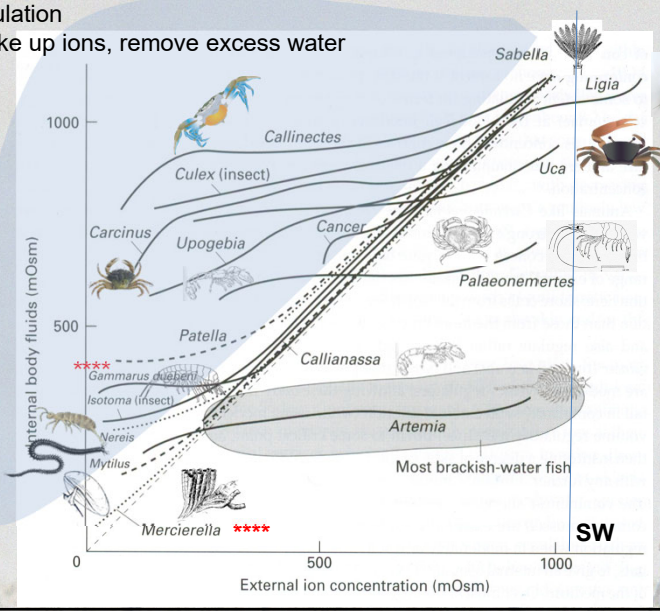
# Osmoregulation:

Hyper-regulation
Need to take up ions, remove excess water

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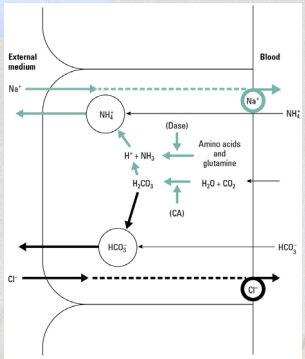
# Culex (mosquito larva): anatomical/physiological adaptations

Active salt uptake




Sodium uptake:
Sodium/Ammonium exchange

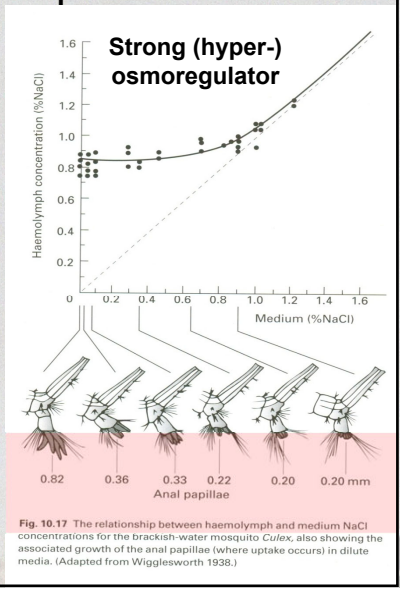



Fig. 10.17 The relationship between haemolymph and medium NaCl concentrations for the brackish-water mosquito *Culex*, also showing the associated growth of the anal papillae (where uptake occurs) in dilute media. (Adapted from Wigglesworth 1938.)

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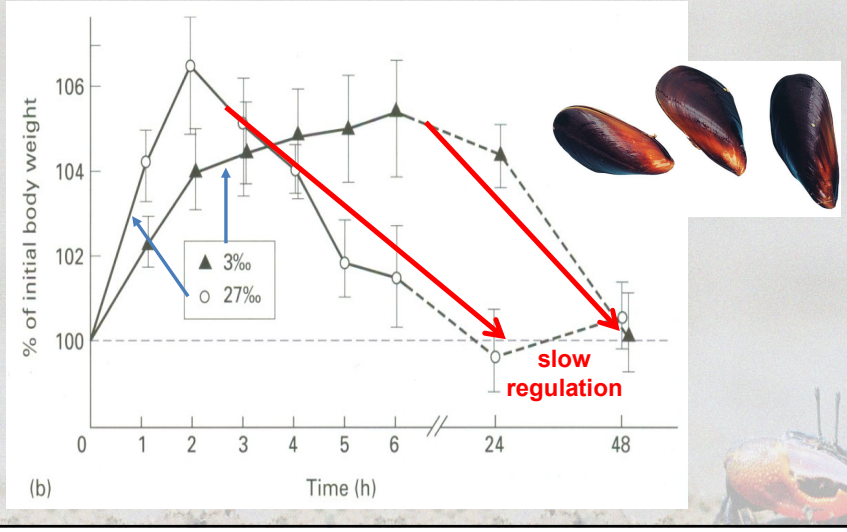
# Volume regulation

Mussel – slow volume regulation – but it has a shell that it can close (especially at 3‰)!

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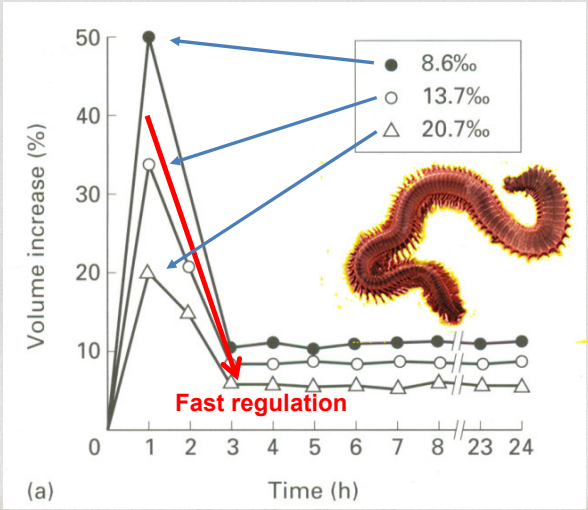
# Fast volume regulation

Estuarine polychaete – fast volume regulation

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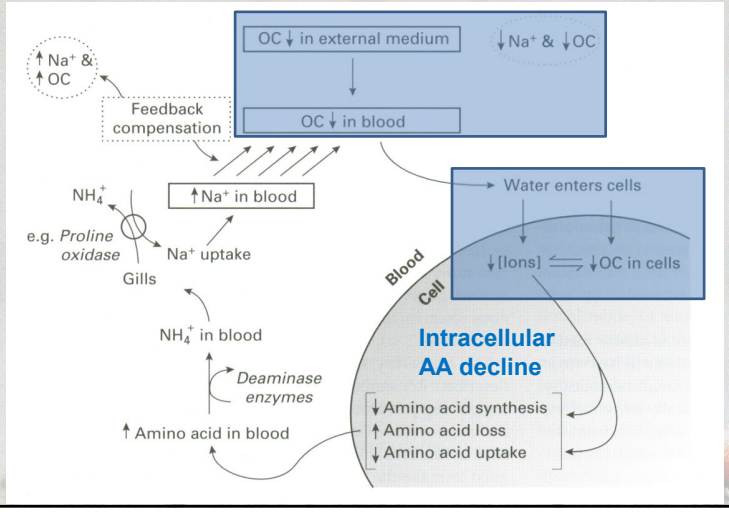
# Intracellular Volume Regulation

If move to more dilute medium, first …..

All solutes decline inside cells

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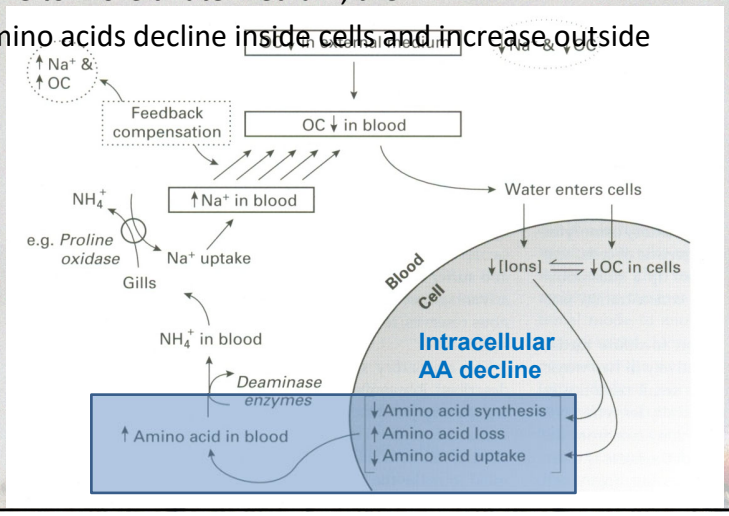
# Intracellular Volume Regulation

If move to more dilute medium, then …..

amino acids decline inside cells and increase outside

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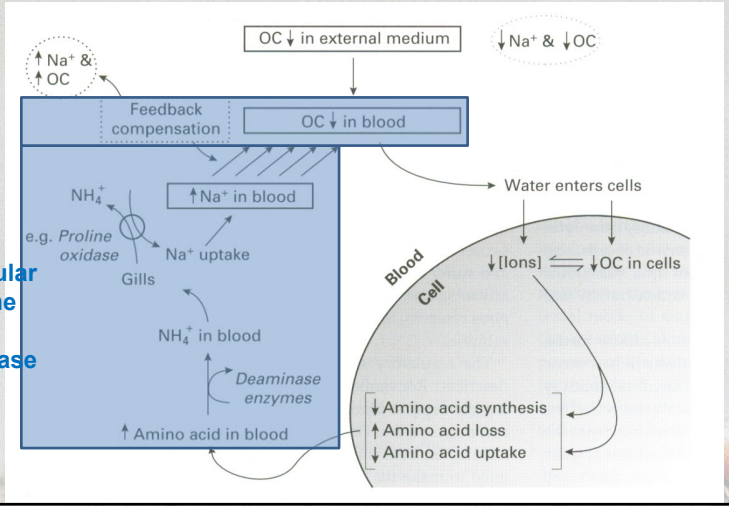
# Extracellular Volume Regulation

then …. deamination increases NH4+ thence Na+ by exchange, to increase OC




**Extracellular AA decline and $Na^+$ increase**

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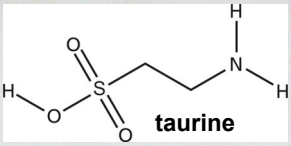
# Volume regulation

Amino acid synthesis –flounder ventricle



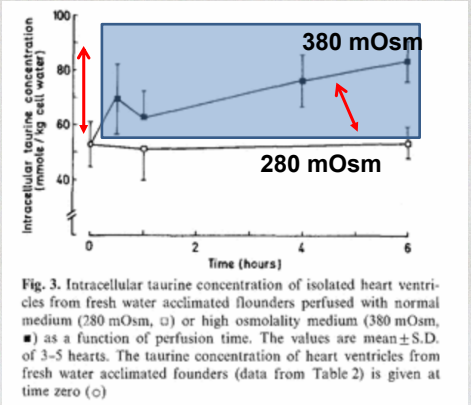




Fig. 3. Intracellular taurine concentration of isolated heart ventricles from fresh water acclimated flounders perfused with normal medium (280 mOsm, □) or high osmolality medium (380 mOsm, ■) as a function of perfusion time. The values are mean ± S.D. of 3–5 hearts. The taurine concentration of heart ventricles from fresh water acclimated founders (data from Table 2) is given at time zero (○)

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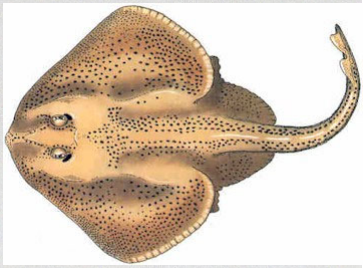
# Volume regulation

Amino acids and urea levels – elasmobranchs
e.g. *Raja erinacea*

Which amino-acids? It varies!
Even between tissues.



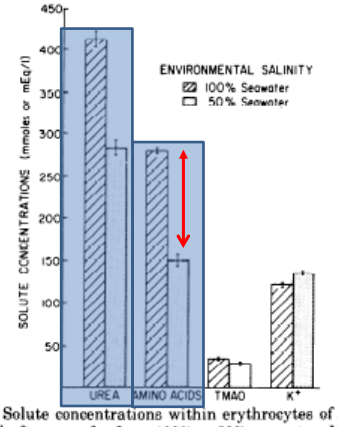



FIG. 2. Solute concentrations within erythrocytes of *R. erinacea* before and after transfer from 100% to 50% seawater. Means ± SE are shown; $n = 6$ for 100% SW; $n = 7$ for 50% SW.

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# Four components of hyper-osmoregulation

- Reduce the permeability of the body surface to salt and water
- Reduce the osmotic gradient across the body surface

→ This reduces the cost of the next two components

- Increased production of (hypo-osmotic) urine to remove passive inflow of water
- Actively absorb salt (mainly NaCl) to counteract the passive, diffusive loss of salt

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# But how do you get rid of the excess water?

FW animals produce lots of dilute urine …using protonephridia/metanephridia, etc

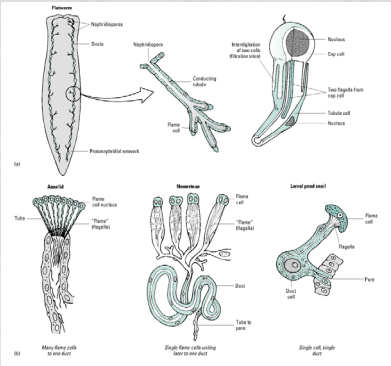

**Table 13.10** Urine concentrations and flow rates in freshwater animals.

| Species | Flow rate (ml kg$^{-1}$ h$^{-1}$) | Concentration (mOsm) | Urine : blood ratio |
|---|---|---|---|
| **Annelids** | | | |
| *Pheretima* | | 45 | 0.19 |
| **Crustaceans** | | | |
| *Orconnectes* | 1.3 | | |
| *Pseudotelphusa* | 0.13 | 120 | |
| *Eriocheir* | | 800 | 1.04 |
| *Gammarus* | 21 | | |
| **Molluscs** | | | |
| *Viviparus* | 6 | 30 | |
| *Anodonta* | 19 | 25 | |
| **Fish** | | | |
| *Carassius* | 14 | | |
| *Salmo* | 5 | | |
| *Lampetra* | 7 | | |
| *Esox* | | 30 | 0.09 |

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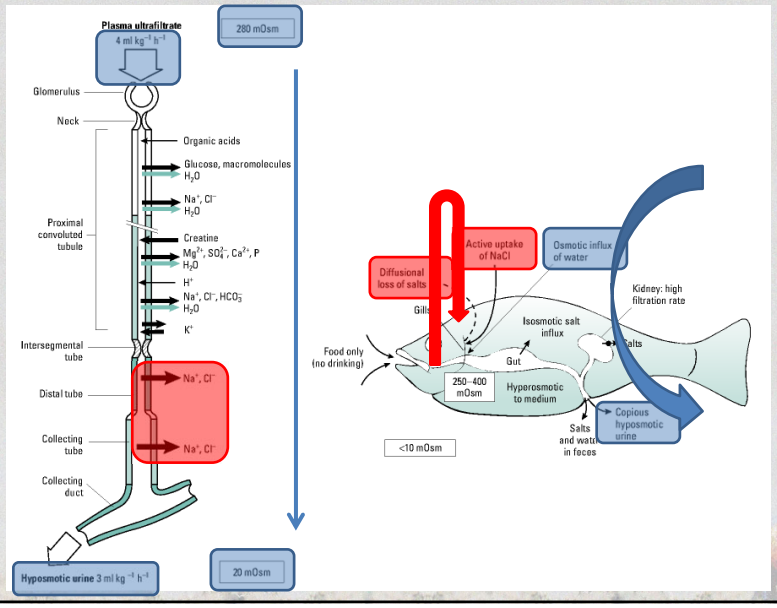
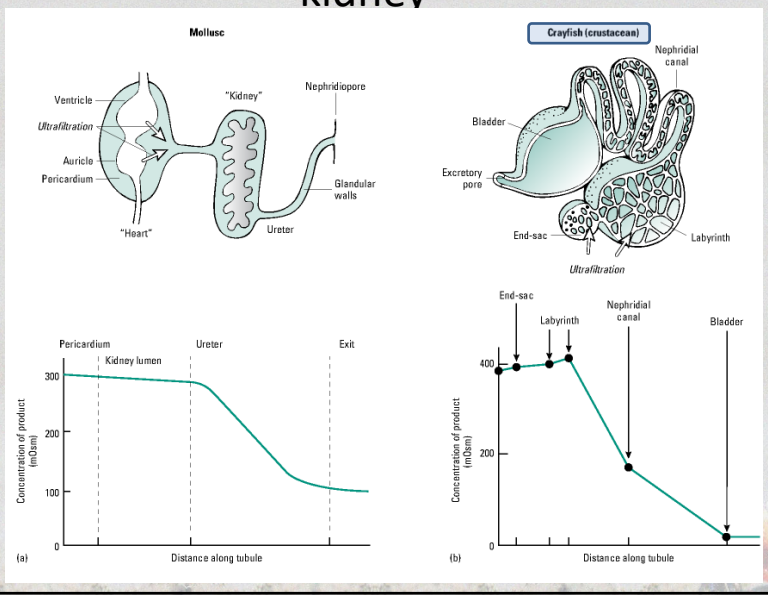
# FW fish – same problems, same solutions




22

# De-salinating urine is not done in the kidney